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QUARTERLY PROGRESS REPORT NUMBER 9, 1 AUGUST-31 OCTOBER 1968.(U)
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DEFENSE RESEARCH LABORATORY

THE UNIVERSITY OF TEXAS AT AUSTIN

13 December 1968

Copy No. 1

QUARTERLY PROGRESS REPORT NO. 9 UNDER CONTRACT NObsr-95181 (U)

1 August -31 October 1968

NAVAL SHIP SYSTEMS COMMAND
Contract NObsr-95181
Project Serial No. SF 1010316, Task 8614

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1 August -31 October 1968.

NAVAL SHIP SYSTEMS COMMAND
Contract NObsr-95181
Project Serial No. SF 1010316, Task 8614

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I. INTRODUCTION

(U-~~FOUO~~) The efficiency in computing the Cepstrum of narrow band signals has been increased by the use of direct quadrature sampling of narrow band signals. As a practical application of Cepstrum to sonar, this is an important step. It means that a Cepstrum can be computed rapidly on a general purpose computer without the use of fast special purpose hardware. As soon as the programming is perfected, the new method will be used to analyze more real data. One of the purposes will be to test the ping-to-ping stability of selected submarine data.

(U-~~FOUO~~) More work was done on a vocoder analysis of active sonar returns. This work has been interesting, but due to a lack of time it will have to be discontinued.

(U-~~FOUO~~) A very efficient program to compute quadrature crosscorrelations based on the fast Fourier transform (FFT) was developed. A figure is presented showing its computational speed versus the number of lags computed (see Fig. 7).

II. CEPSTRUM ANALYSIS

(J. A. Shooter)

(C) In Quarterly Progress Report No. 8 on Contract NObsr-95181 (U), it was shown that the power spectrum of a narrow band signal can be computed directly from the signal's quadrature components. The computation time thus saved was approximately a factor of 16. This technique has now been successfully applied to computing the Cepstrum of a narrow band signal. An illustration is shown in Fig. 1, the data in this case being a return from a stern aspect submarine. The transmitted signal was a linear FM sweep with a bandwidth W of 625 Hz, a time bandwidth product TW of 64, and a carrier frequency, f_o, of 5000 Hz. Each quadrature component was sampled at a rate of 2W. The power spectrum of the positive frequencies is shown in Fig. 1a. The frequency axis begins at $f = f_o$, and f increases to $f = f_o + W$ at the center of the plot. Then f changes to $f = f_o - W$ and increases to f_o at the end of the frequency axis. This rather strange frequency axis is in keeping with the Cooley-Tukey version of the fast Fourier transform, and it is necessary to leave it in that order so that the next Fourier transformation will put the Cepstrum peaks in the correct position. This is not a symmetrical function.

(U-~~FOUO~~) The next step in computing a Cepstrum is shown in Fig. 1b, which is a filtered logarithm of Fig. 1a. In this case, it was assumed that the log power was a time series sampled at 20 kHz. The filter was a recursive band-pass 1-pole Butterworth filter set at 350 to 6000 Hz. The filter frequency limits are related to the time delays between superimposed waveforms or target size. The upper and lower limits cover target sizes from stern to beam aspects. In addition, to remove ringing due to the filter, the first and last 10% of the filtered log power was smoothed to zero by half cosine bells.

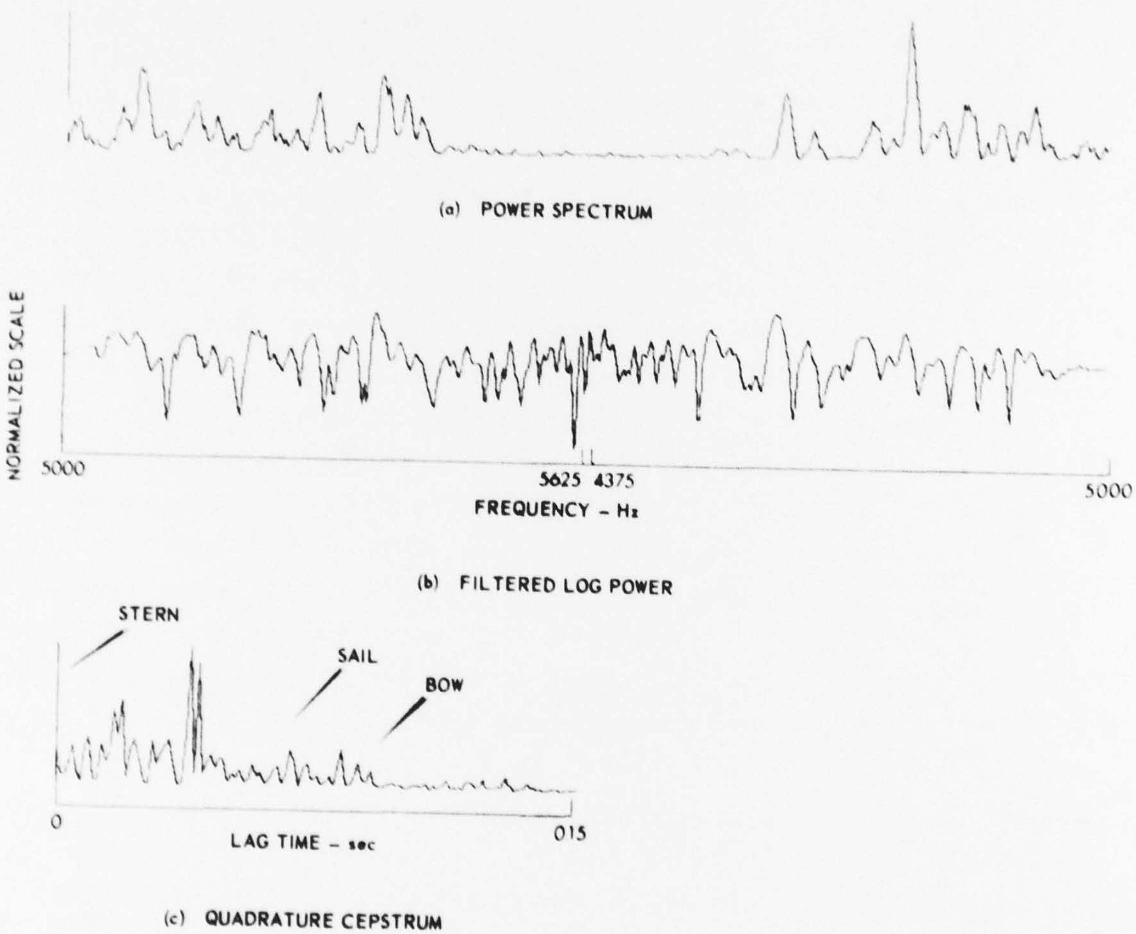

FIGURE 1
COMPUTATION OF A CEPSTRUM IN QUADRATURE
FOR STERN ASPECT SUBMARINE DATA (U)

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(C) The last step shown in Fig. 1c is the square of the modulus of the Fourier transform of Fig. 1b. In addition, a Hanning window was applied to the real and imaginary components before squaring. This final result is the Cepstrum. For 512 quadrature components, each sampled at twice the bandwidth, the computation time for the Cepstrum was about 3 sec. This was using FORTRAN language on a Control Data Corporation 3200 computer. In machine language on an ordinary general purpose computer there should be no trouble in computing a Cepstrum in less than 1 sec. The quadrature Cepstrum is actually the envelope of the Cepstrum, and the results are interpreted in the following manner. The main peak is a correlation of a strong highlight midway between the stern and the sail with the highlight from the sail. The correlations between the highlights of stern and of the bow are very weak, and they are almost lost in the noise.

(U-~~FOUO~~) These results are quite encouraging. The next few experiments will determine the proper data lengths to prevent "wrap around" and to optimize the signal-to-noise ratios. Once the data lengths are settled, then a ping-to-ping stability test will be carried out to determine the suitability of Cepstrum as an aid in classification of submarine echoes.

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III. VOCODER ANALYSIS OF ACTIVE SONAR DATA

(J. A. Shooter and R. E. Senterfitt)

(U-~~FOUO~~) In QPR No. 8 on Contract NObsr-95181 (U), an effort was made to display an FM return on a time vs frequency plot. The results at that time were puzzling. It is now known that the difficulty was in the fact that the overlapping FM waveforms can interfere to produce peaks in the plots. This is demonstrated in Fig. 2, which shows a vocoder plot of four closely spaced overlapping waveforms. In these, artificial data are used and each of the waveforms is identical. It is seen that the output of each filter is unique, and therefore the peaks should not be interpreted as highlight structure.

(U-~~FOUO~~) This is not to say that a time-frequency plot could not be useful. Figures 3, 4, 5, and 6 show vocoder plots of a bow aspect submarine. These represent four consecutive pings, and the results are consistent. At this time, the peaks have no meaning, other than to say that the target is complex. The high frequency ripple superimposed on the large peaks are caused by frequency leakage through a rather poor filter, and they have no meanings.

(U-~~FOUO~~) This could be an interesting problem as related to echo classification, but time does not allow its perusal.

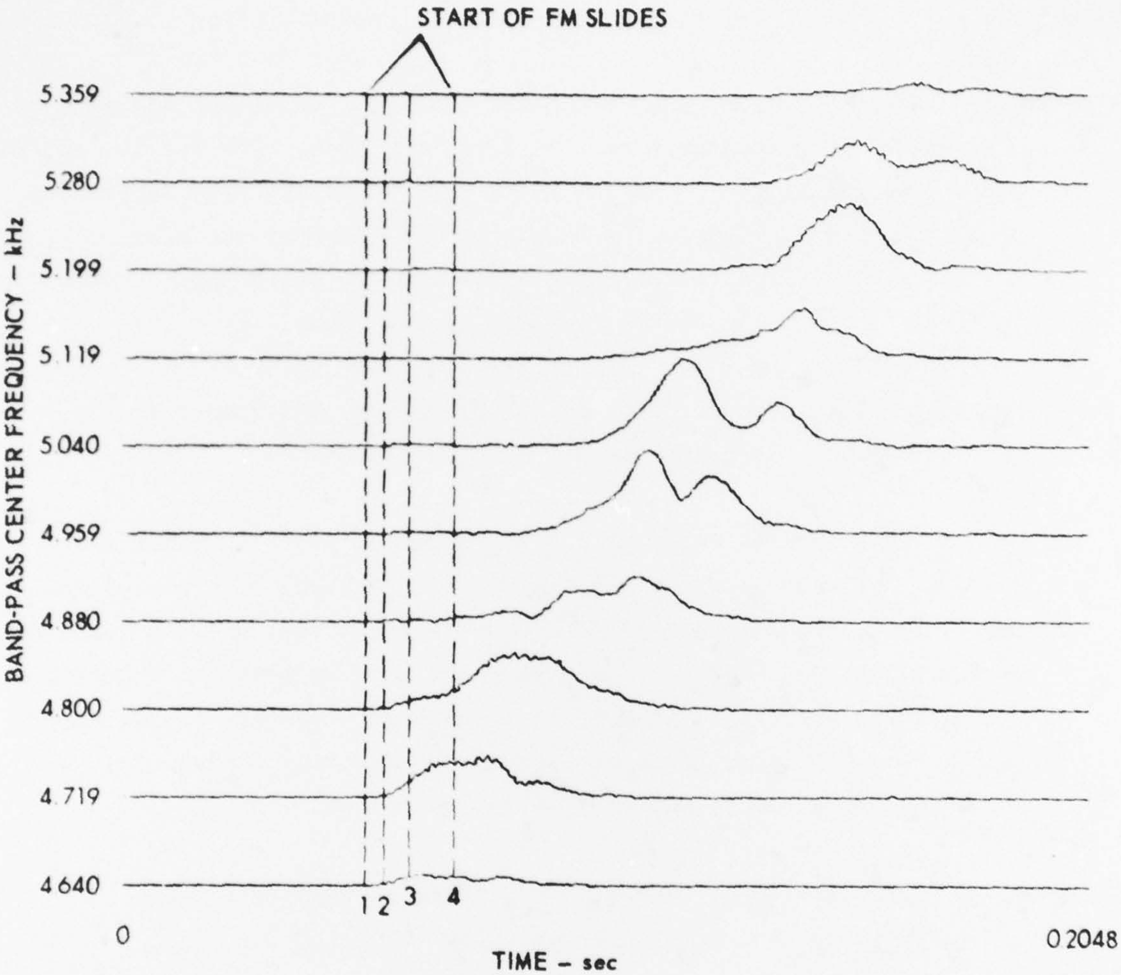

FIGURE 2
VOCODER ANALYSIS OF ARTIFICIAL DATA
TW = 64 W = 625 Hz f_0 = 5000 Hz

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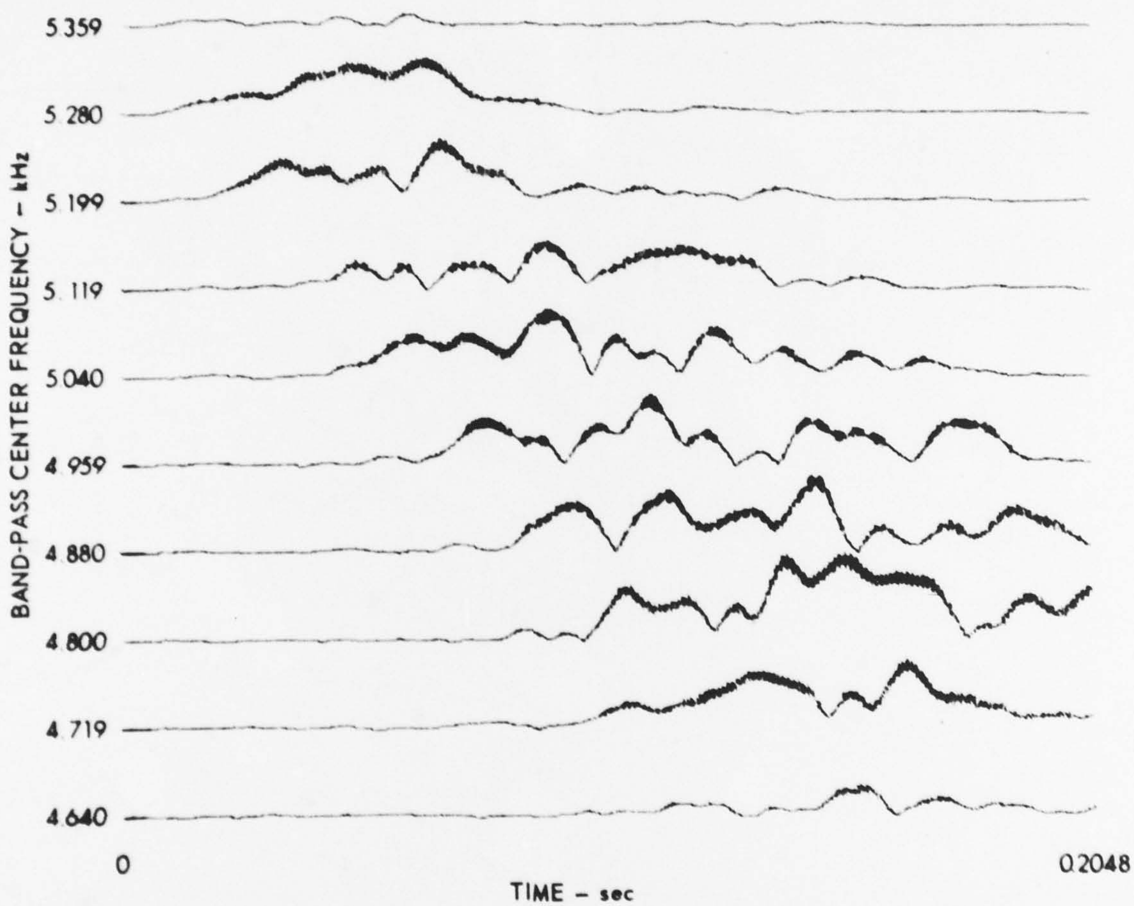

FIGURE 3
VOCODER ANALYSIS OF
BOW ASPECT SUBMARINE DATA (U)
TW = 64 W = 625 Hz f_0 = 5000 Hz
SEQUENCE 13 TAPE 244

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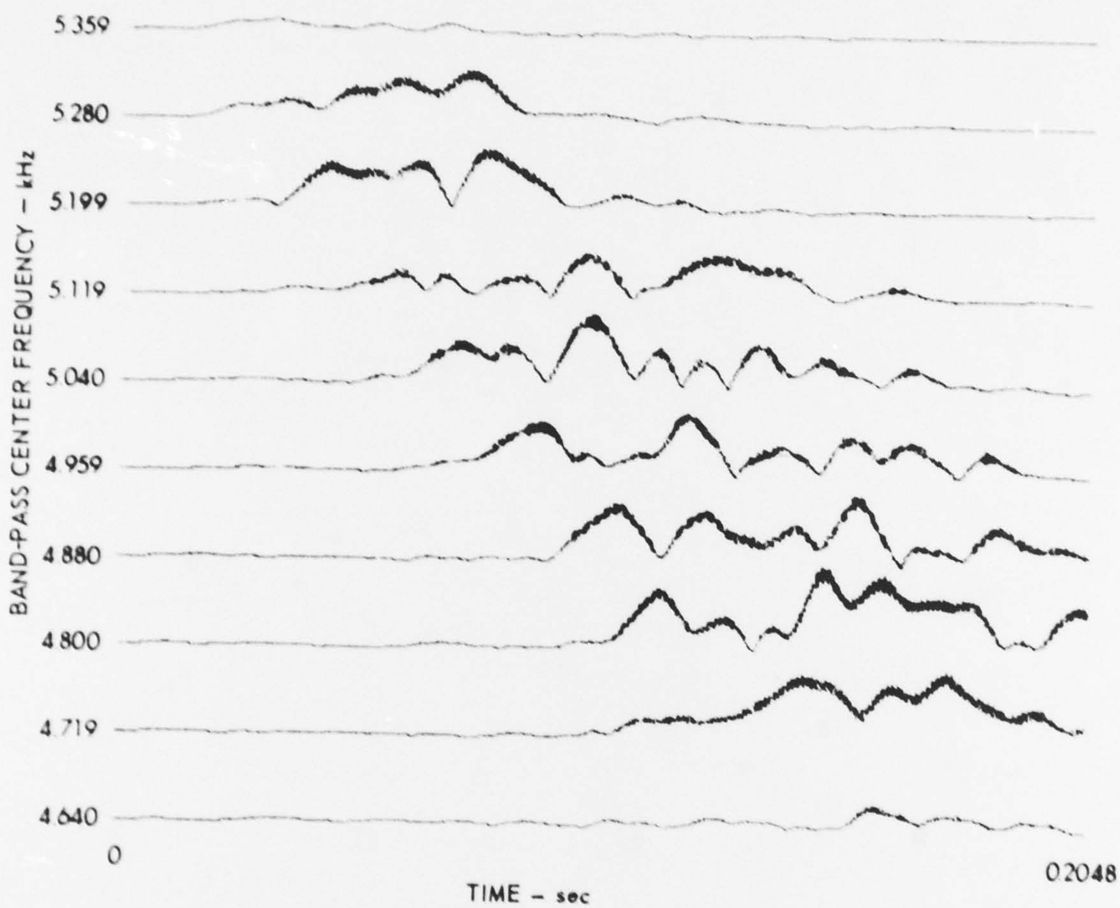

FIGURE 4
VOCODER ANALYSIS OF
BOW ASPECT SUBMARINE DATA (U)
TW = 64 W = 625 Hz f_0 = 5000 Hz
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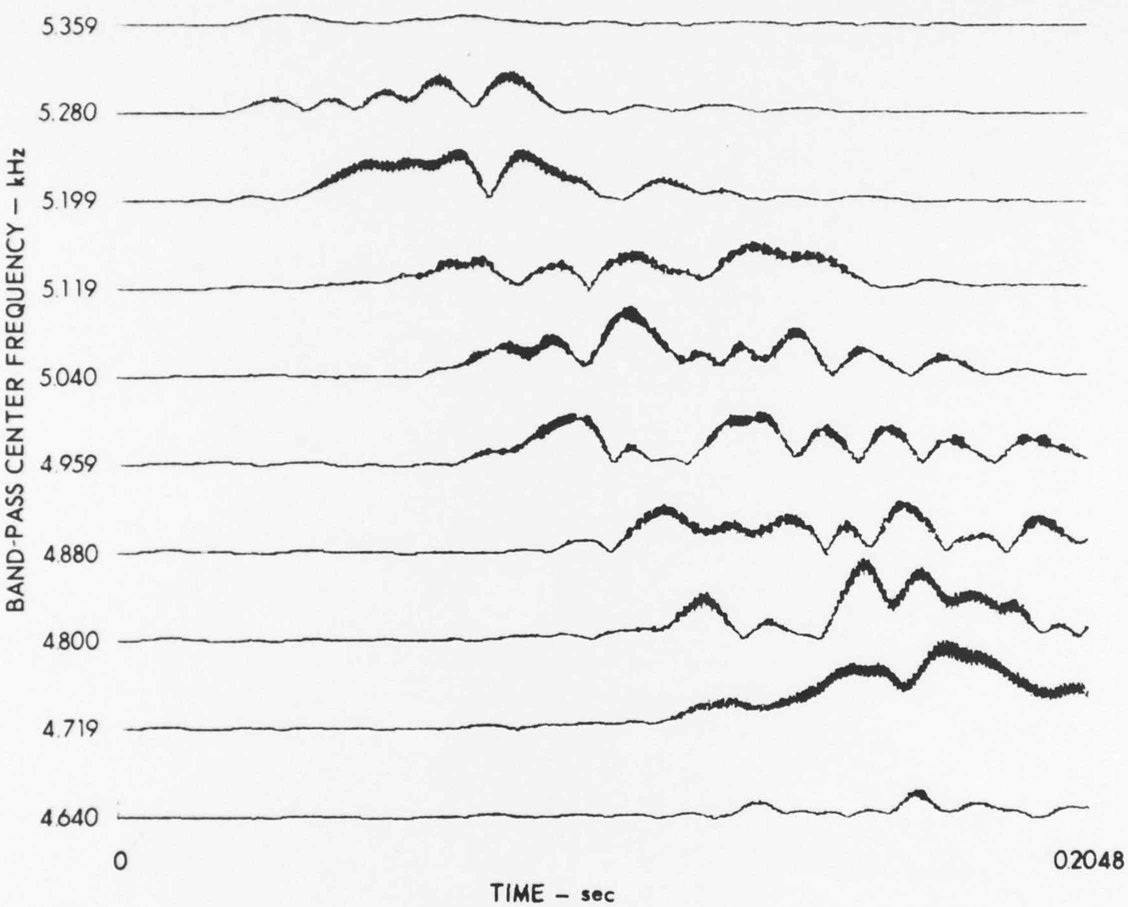

FIGURE 5
VOCODER ANALYSIS OF
BOW ASPECT SUBMARINE DATA (U)
TW = 64 W = 625 Hz f_0 = 5000 Hz
SEQUENCE 15 TAPE 244

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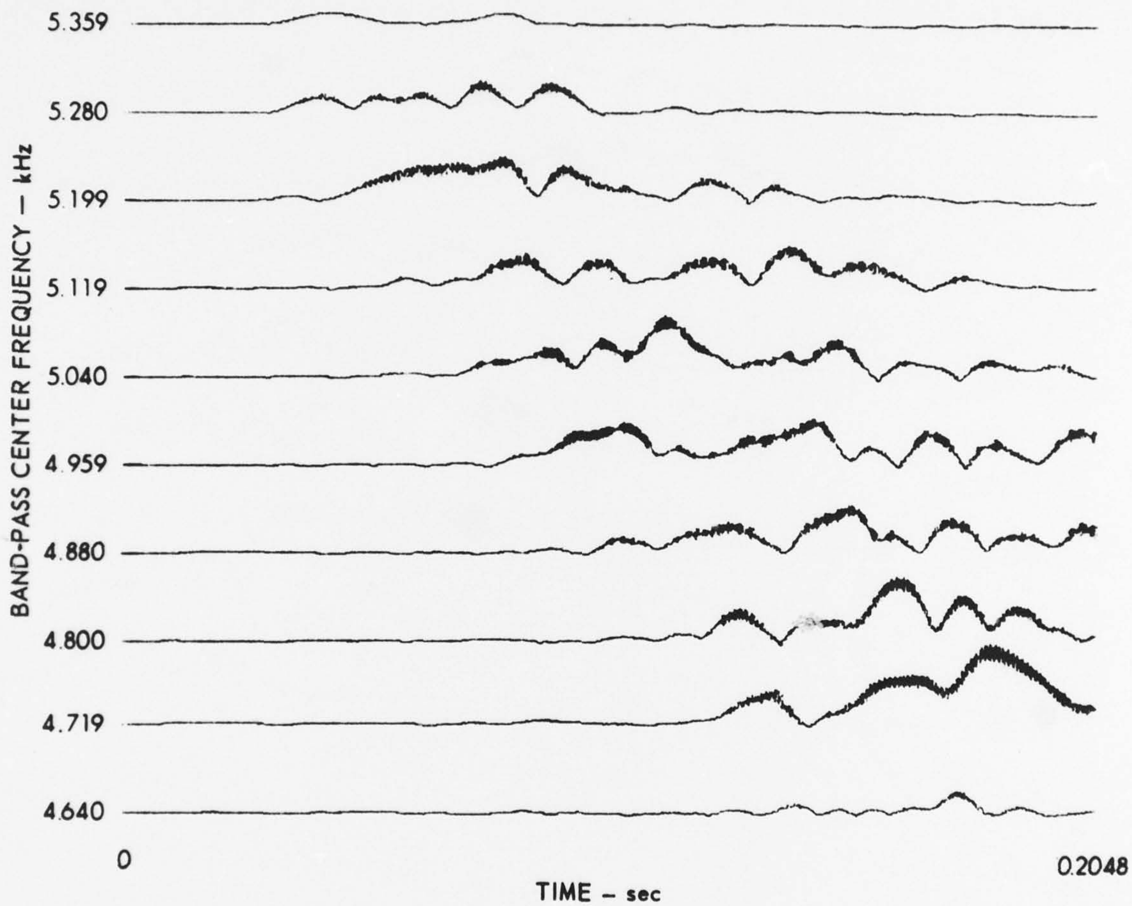

FIGURE 6
VOCODER ANALYSIS OF
BOW ASPECT SUBMARINE DATA (U)
TW = 64   W = 625 Hz f_0 = 5000 Hz
SEQUENCE 17   TAPE 244

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JAS - RFO
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IV. QUADRATURE CORRELATION

(J. A. Shooter)

(U-~~FOUO~~) Early in this quarter a computer program was developed to compute a quadrature crosscorrelation, based on the fast Fourier transform (FFT). To check the program, a comparison was made on identical sets of data using the FFT version and a program developed by the Signal Physics Division. The results were identical, and they are shown in Fig. 6 of QPR No. 3 on Contract N00024-68-C-1149 (U). Unfortunately, the FFT version was embarrassingly slow. A new version has just been developed that takes advantage of the symmetrical properties of the Fourier transformations of real numbers. The new version (FQFT) is now operational, and Fig. 7 shows the comparative computational times. The FFT program must compute data in blocks of powers of two, which accounts for the stairstep function shown in the figure. The two curves showing computational time intersect 5 times, and potential users will have to refer to Fig. 7 to decide which program to use for economy of time. The FFT program is written in FORTRAN and does floating point arithmetic, so that it can still be improved.

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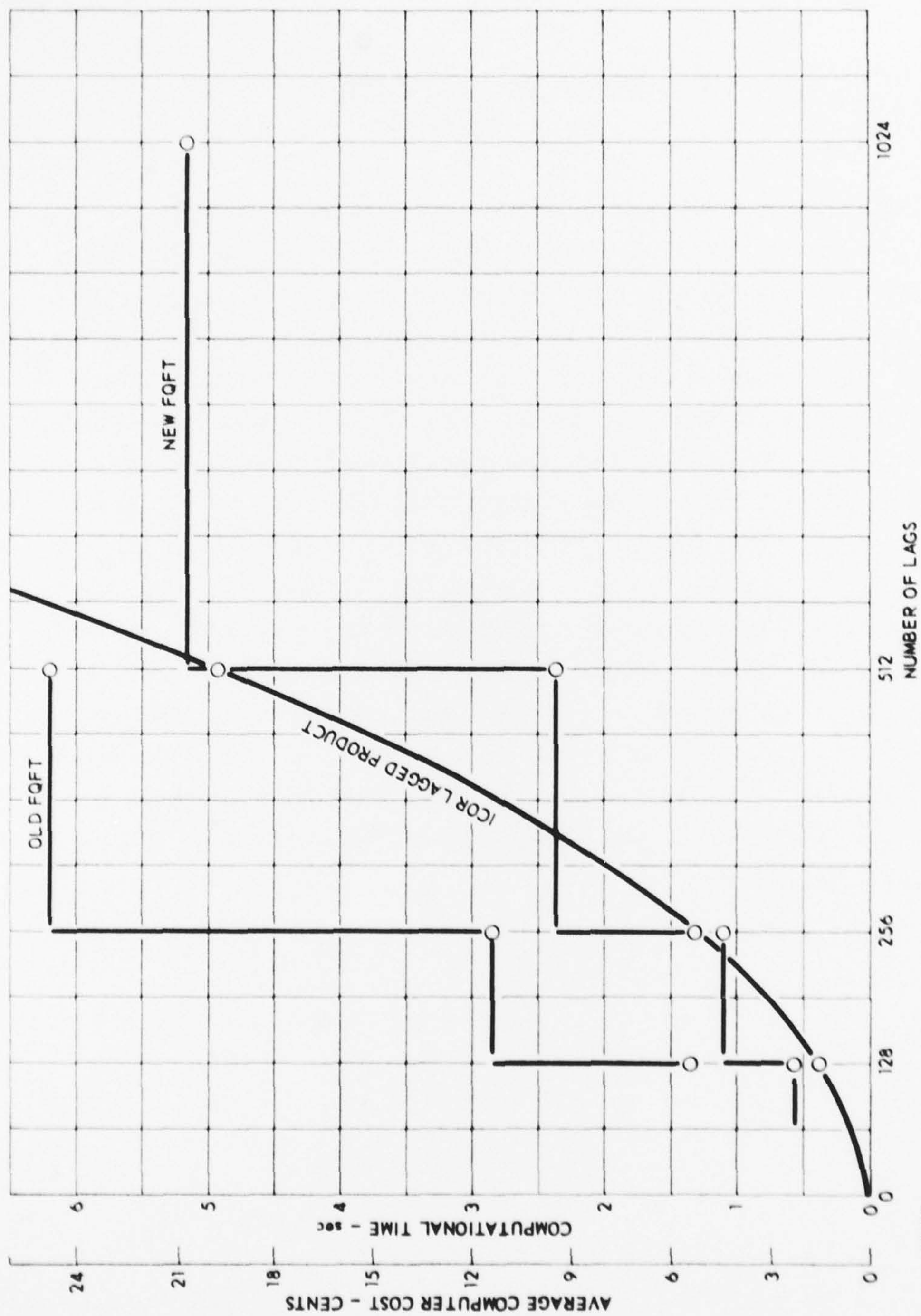

FIGURE 7
COMPUTATIONAL TIMES FOR THREE PROGRAMS
COMPUTING QUADRATURE CROSSCORRELATIONS

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V. REPORTS AND PUBLICATIONS

(J. A. Shooter)

(U-~~FOUO~~) The joint paper on narrow band signal processing by Messrs. O. D. Grace and J. A. Shooter has yet to be written. Miss C. J. Webb is now putting the finishing touches on a report dealing with the practical aspects of time series analysis and the FFT algorithm.

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